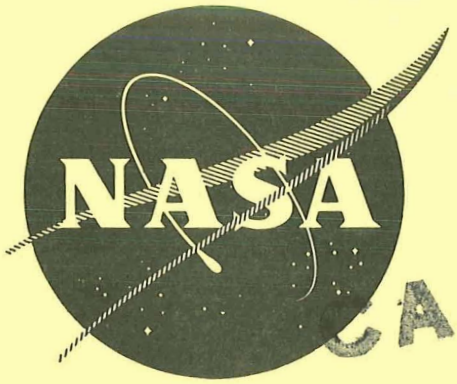

EVALUATION PROGRAM

for

SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST
OF
GULTON INDUSTRIES, INC. & GENERAL ELECTRIC CO.

6.0 AMPERE-HOUR NICKEL-CADMIUM CELLS

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT W12,397

QUALITY EVALUATION LABORATORY

NAD CRANE, INDIANA

QUALITY EVALUATION LABORATORY
NAVAL AMMUNITION DEPOT
CRANE, INDIANA

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GULTON INDUSTRIES, INC. AND GENERAL ELECTRIC COMPANY
6.0 AMPERE-HOUR
NICKEL-CADMIUM CELLS

QE/C 70-690 28 AUGUST 1970

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Enclosure (1)

QE/C 70-690

REPORT BRIEF
6.0 AMPERE-HOUR SEALED NICKEL CADMIUM SECONDARY SPACECRAFT CELLS DESIGNATED FOR USE IN SMALL ASTRONOMICAL SATELLITE (SAS) MANUFACTURED BY GULTON (SAS A) AND GENERAL ELECTRIC (SAS B)

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W12-397
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961
(d) Work sheet of 2 February 1970

I. TEST ASSIGNMENT BRIEF

A. In compliance with references (a) and (b), evaluation of 6.0 ampere-hour secondary spacecraft cells was begun according to the program outline of reference (c).

B. The object of this evaluation program is to gather information concerning secondary spacecraft cells, in general. More specifically, these cells are being evaluated for their use in the SAS program as specified in reference (d). Information concerning performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power systems designers and users. Cell weaknesses, including causes of failure of present designs, will be of interest to suppliers as a guide to product improvement.

C. Twenty 6.0 ampere-hour cells (manufacturer's rating) were purchased by the Applied Physics Laboratory and were tested by NAD Crane under the direction of NASA Goddard. Ten were manufactured by Gulton Industries; ten were manufactured by General Electric.

II. RESULTS

A. The ceramic seals of these cells are satisfactory as evidenced by no leakers out of the 20 cells tested.

B. The capacity of the 20 cells tested was acceptable. It ranged from 6.84 to 7.65 ampere-hours for both the Gulton and General Electric cells. The respective averages were 7.24 and 7.44 ampere-hours.

C. None of the 20 cells indicated internal shorts. The 24-hour recovery voltage was in the acceptable range of 1.18 to 1.22 volts for both groups of cells. Both groups averaged 1.19 volts on recovery.

D. Both groups gave satisfactory performance on overcharge. There was essentially no variance in end-of-overcharge values at each of the three rates run for both test groups. The average value was 1.43 volts.

E. The internal resistance of the Gulton cells averaged 3.90 milliohms; that of the General Electric cells averaged 4.26 milliohms.

F. The capacity to 1.00 volt following overcharge averaged 6.83 ampere-hours for the Gulton cells and 7.21 ampere-hours for the General Electric cells.

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RESULTS OF ACCEPTANCE TESTS OF 6.0 AMPERE HOUR NICKEL-CADMIUM SECONDARY SPACECRAFT CELLS EVALUATED FOR USE IN SAS SATELLITE

I. INTRODUCTION

A. On 27 May 1970 acceptance tests were begun on 20 cells--10 manufactured by Gulton Industries and 10 manufactured by General Electric. These tests were completed on 10 June 1970.

II. TEST CONDITIONS

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure, and consisted of the following:

1. Physical Inspection: Weighing, Measuring and Phenolphthalein Leak Test.
2. Capacity Tests.
3. Cell Short Test.
4. Leak Test.
5. Overcharge Test.
6. Internal Resistance Measurement.
7. Leak Test.

B. All charging and discharging was done at constant current (± 5 percent). Cells were charged in series but discharged individually.

III. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers. However, there were two packs of ten cells, each manufactured by a different company. The serial numbers of those cells manufactured by Gulton Industries were from 1937 to 1994; those manufactured by General Electric were from 013 to 057. The numbering was not consecutive in either group.

B. The 6.0 ampere-hour cells of each group are rectangular. The average dimensions and weight are included in Table I along with the individual measurements of each cell.

C. The cell containers and covers of each group are made of stainless steel. The positive terminal of each cell in either group is insulated from the cell cover by a ceramic seal which protrudes from the cover as a solder type terminal. The General Electric cells have a solder tab welded to both terminals while the Gulton cells do not. The negative terminals of either group are welded to the cell covers.

D. These cells, rated at 6.0 ampere-hours by their respective manufacturers, were supplied in a discharged condition.

IV. TEST PROCEDURE AND RESULTS

A. Phenolphthalein Leak Test:

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seals on receipt of the cells. This test was performed prior to any other tests, with a phenolphthalein spray indicator solution of one-half of one percent concentration.

2. One cell (SN 1940) indicated a leak and some corrosion at the positive terminal. However, no leaks were detected on later leak tests. Thus, electrolyte contamination prior to shipment may account for such results.

B. Capacity Tests:

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, where c is the manufacturer's rated capacity to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the c/10 rate. A total of three capacity checks was made at this activity. The cells were discharged individually, but were recharged in series.

2. The individual capacities for the cells of both manufacturers ranged from 6.84 to 7.65 ampere-hours. The Gulton cells averaged 7.24 ampere-hours and the General Electric cells averaged 7.44 ampere-hours.

C. Cell Short Test:

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge test, each cell was loaded with a 0.5 ohm, 3 watt resistor and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.15 volts or higher was considered as failing this portion of the acceptance test.

3. The open circuit voltage, 24 hours after removal of the shorting resistors, ranged from 1.18 to 1.22 volts for an average of 1.19 volts. No cells failed this test.

D. Leak Test

1. The leak test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence of leaks.

2. The cells were placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. The cells were then removed from the vacuum chamber and sprayed with phenolphthalein. Faintly pink areas were designated as slight leakers. Darker, more obvious, discolorations of pink or red were noted as definite leakers.

3. None of the 20 cells failed this portion of testing.

E. Overcharge Test:

1. The purpose of this test is basically threefold:

a. To determine the degree to which a pack of cells maintain a balanced voltage.

b. To determine the cells capability of reaching a point of chemical equilibrium--oxygen recombination with the negative (cadmium) plate.

c. To test the integrity of the seals as the pressure increases.

2. The overcharge tests were performed to determine the steady state voltage at specified rates. The test specified a series of constant current charges at c/10, c/20 and c/10 for a minimum of 16 hours at each charge rate.

3. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts. No cells were removed from the charging sequence.

4. The steady state voltage of each cell at the end of each 16-hour charge rate is shown in Table I. Characteristic overcharge voltage curves for high, average and low cells are shown in Figure 2.

F. Internal Resistance Test:

1. Immediately following the overcharge test, the internal resistance of each cell was measured with a Hewlett-Packard milliohmmeter (Model 4328A).

2. The internal resistance for each cell is shown in Table I. The resistance values for the Gulton cells ranged from 3.75 to 3.99 milliohms for an average of 3.90 milliohms; the General Electric cells ranged from 3.97 to 4.78 milliohms for an average of 4.26 milliohms.

G. Leak Test:

1. Following the internal resistance measurements, the cells were still in a charged state. The cells were discharged at c/2 to 0.00 volts and shorted prior to the final leak test. The capacities to 1.00 volt prior to the 0.00 volt cut-off are shown for each cell in Table I. The shorted cells were then placed in a vacuum chamber and the procedure described in paragraph IV.D.2 was repeated.

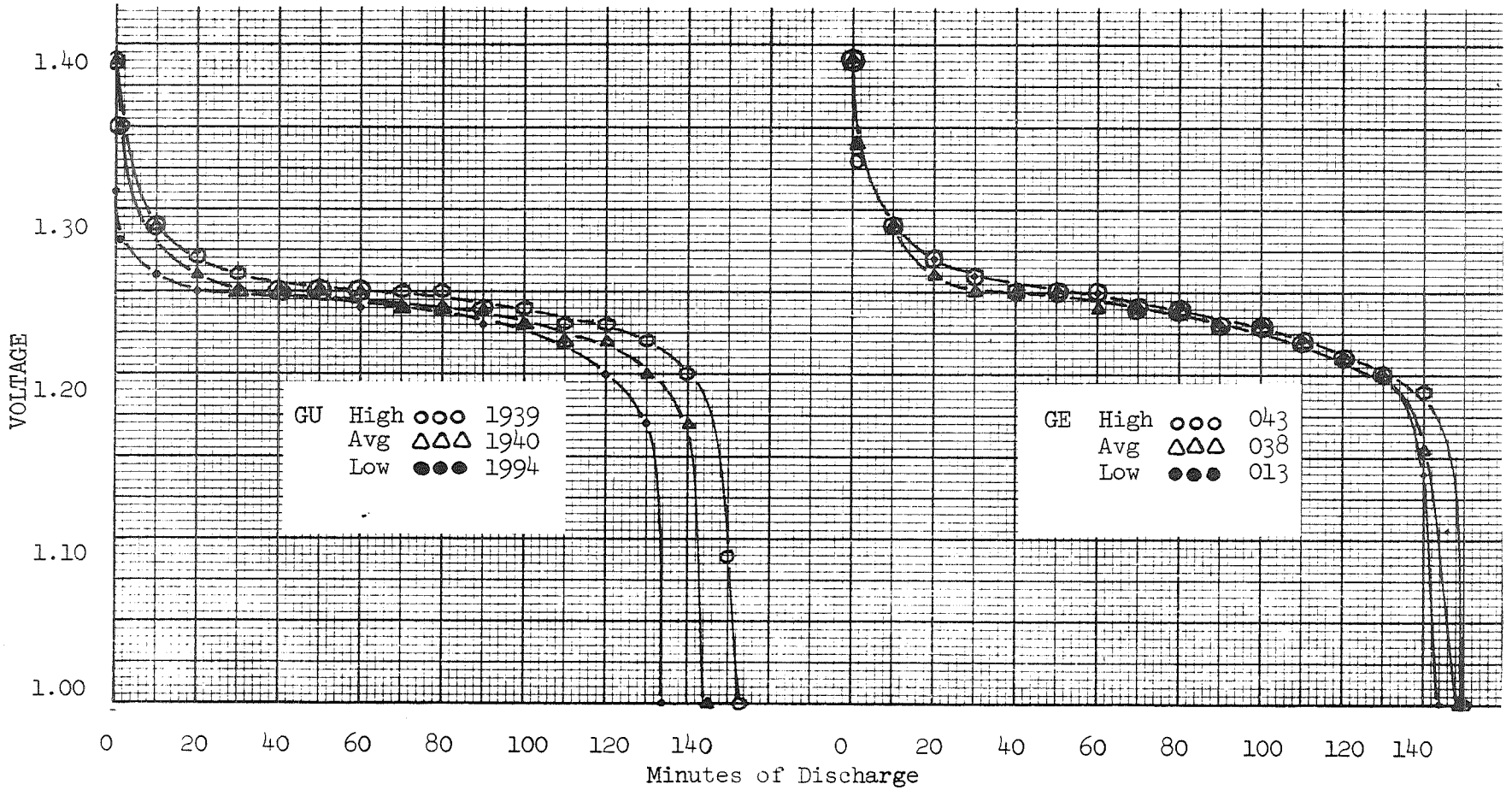
2. None of the 20 cells failed this portion of the testing.

TABLE I
6.0 AMPERE-HOUR CELLS EVALUATED FOR USE IN SAS SATELLITE
MANUFACTURED BY GULTON (SAS A) AND GENERAL ELECTRIC (SAS B)

	CELL SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	CAPACITY No. 1 (Amp-Hr)	CAPACITY No. 2 (Amp-Hr)	CAPACITY No. 3 (Amp-Hr)	CELL SHORT TEST	c/10 OVERCHARGE FOR 16 HRS (Volts)	c/20 OVERCHARGE FOR 16 HRS (Volts)	c/10 OVERCHARGE FOR 16 HRS (Volts)	INTERNAL RESISTANCE (Milliohms)	CAPACITY FOLLOWING OVERCHARGE TO 1.0 VOLT (Amp-Hr)
E-3-0	1937	271.8	3.710	0.819	2.100	7.35	7.20	6.99	1.22	1.43	1.43	1.45	3.99	6.69
	1939	273.5	3.698	0.823	2.099	7.65	7.50	7.59	1.19	1.43	1.44	1.45	3.85	7.26
	1940	269.8	3.700	0.824	2.090	7.26	6.96	6.90	1.20	1.42	1.43	1.44	3.90	6.42
	1946	273.1	3.700	0.817	2.098	7.35	7.20	7.05	1.19	1.42	1.43	1.43	3.79	6.75
	1965	271.2	3.704	0.835	2.100	7.41	7.20	7.44	1.18	1.42	1.43	1.44	3.94	6.96
	1968	268.2	3.717	0.830	2.100	7.35	7.05	6.84	1.19	1.42	1.43	1.43	3.88	6.66
	1969	272.1	3.694	0.840	2.098	7.50	7.29	7.29	1.18	1.43	1.43	1.44	3.98	7.14
	1987	271.1	3.698	0.829	2.110	7.41	7.05	7.56	1.19	1.43	1.43	1.43	3.99	6.75
	1992	271.2	3.696	0.827	2.100	7.20	6.96	6.84	1.20	1.43	1.43	1.43	3.75	6.60
	1994	273.9	3.685	0.830	2.101	6.69	7.59	7.59	1.19	1.44	1.44	1.45	3.90	7.05
	Avg.	271.6	3.700	0.827	2.100	7.32	7.20	7.21	1.19	1.43	1.43	1.44	3.90	6.83
E-4-0	013	272.7	3.565	0.848	2.145	7.20	7.20	6.84	1.22	1.42	1.43	1.44	4.39	6.66
	038	271.6	3.563	0.832	2.150	7.44	7.56	7.20	1.19	1.43	1.44	1.44	4.18	7.20
	041	271.8	3.545	0.835	2.142	7.44	7.56	7.20	1.20	1.43	1.43	1.43	4.17	7.14
	043	273.8	3.550	0.831	2.140	7.50	7.65	7.56	1.19	1.43	1.43	1.43	3.99	7.44
	044	273.2	3.549	0.830	2.141	7.50	7.56	7.29	1.20	1.43	1.43	1.43	4.22	7.20

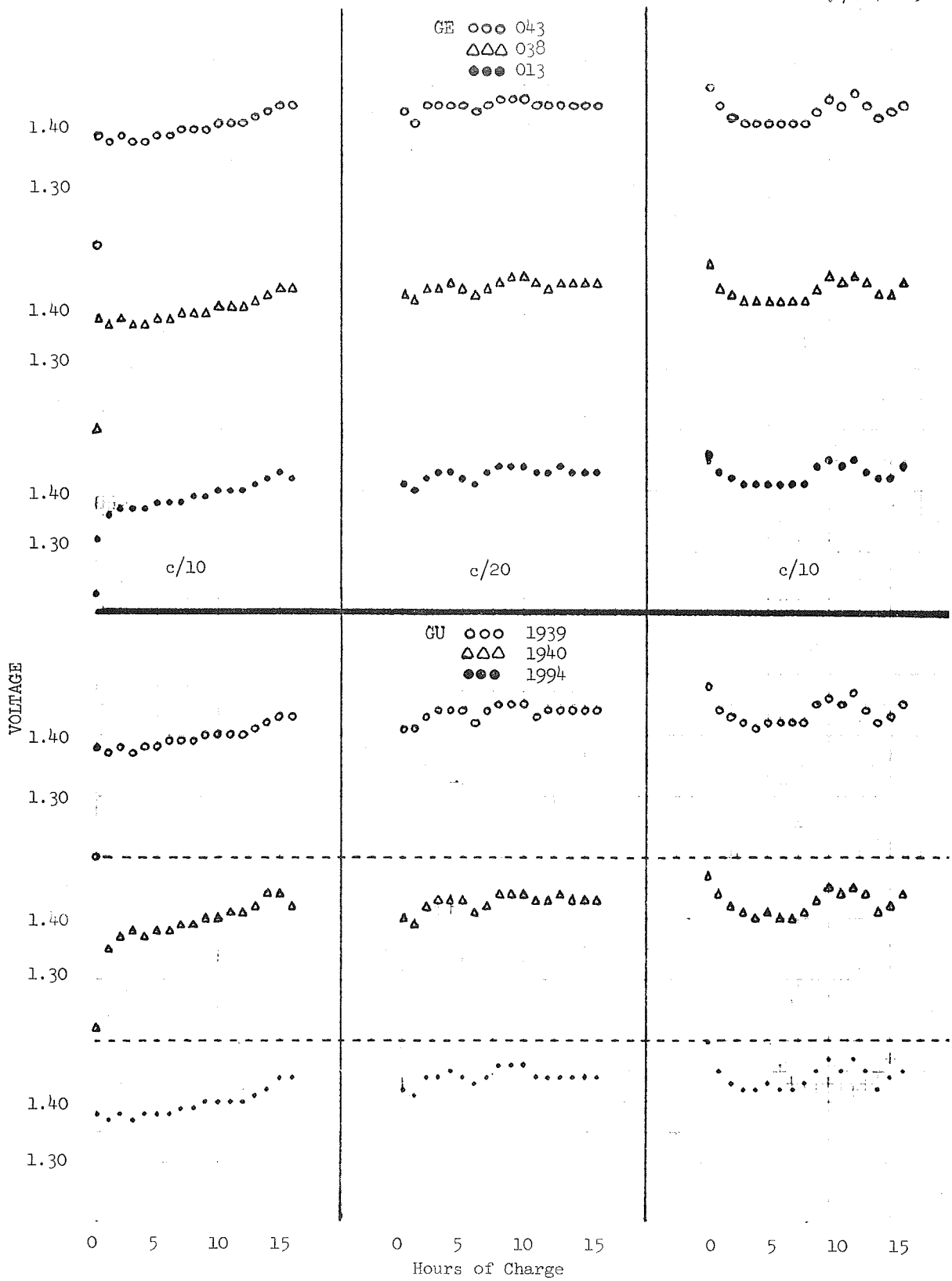
TABLE I

CELL SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	CAPACITY No. 1 (Amp-Hr)	CAPACITY No. 2 (Amp-Hr)	CAPACITY No. 3 (Amp-Hr)	CELL SHORT TEST	c/10 OVERCHARGE FOR 16 HRS (Volts)	c/20 OVERCHARGE FOR 16 HRS (Volts)	c/10 OVERCHARGE FOR 16 HRS (Volts)	INTERNAL RESISTANCE (Milliohms)	CAPACITY FOLLOWING OVERCHARGE TO 1.0 VOLT (Amp-Hr)
052	272.0	3.551	0.830	2.145	7.56	7.71	7.29	1.18	1.43	1.43	1.42	4.11	7.41
053	274.2	3.548	0.840	2.142	7.44	7.56	7.56	1.19	1.43	1.43	1.42	4.18	7.26
054	273.3	3.559	0.832	2.147	7.56	7.59	7.80	1.19	1.43	1.43	1.43	4.63	7.26
055	271.8	3.550	0.852	2.140	7.44	7.44	7.14	1.19	1.42	1.43	1.42	4.78	7.14
057	271.9	3.548	0.831	2.144	7.56	7.65	7.50	1.19	1.43	1.43	1.44	3.97	7.35
Avg	272.6	3.553	0.836	2.144	7.46	7.53	7.34	1.19	1.43	1.43	1.43	4.26	7.21



CHARACTERISTIC 2-HOUR RATE DISCHARGE CURVES
6.0 AMPERE-HOUR CELLS EVALUATED FOR USE IN SAS SATELLITE
MANUFACTURED BY GULTON (SAS A) AND GENERAL ELECTRIC (SAS B)

FIGURE 1



CHARACTERISTIC 16-HOUR OVERCHARGE CURVES
6.0 AMPERE-HOUR CELLS EVALUATED FOR USE IN SAS SATELLITE
MANUFACTURED BY GULTON (SAS A) AND GENERAL ELECTRIC (SAS B)

FIGURE 2

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130 Texas Instruments, Inc., Metals and Controls Division (Dr. E. J. Jost and Dr. J. W. Ross), 34 Forest Street, Attleboro, Massachusetts 02703

131 TRW Systems, Inc. (Dr. W. R. Scott, M 2/2154), One Space Park, Redondo Beach, California 90278

132 TRW Systems, Inc. (Dr. Herbert P. Silverman, R-1/2094), One Space Park, Redondo Beach, California 90278

133 TRW, Inc. (Librarian), 23555 Euclid Avenue, Cleveland, Ohio 44117

134 Tyco Laboratories, Inc. (Dr. A. C. Makrides), Bear Hill, Hickory Drive, Waltham, Massachusetts 02154

135 Union Carbide Corporation, Development Laboratory Library, P. O. Box 5056, Cleveland, Ohio 44101

136 Union Carbide Corporation, Consumer Products Division (Dr. Robert Powers), P. O. Box 6166, Cleveland, Ohio 44101

137 University of Pennsylvania, Electrochemistry Laboratory (Prof. John O'M. Bockris), Philadelphia, Pennsylvania 19104

138 Westinghouse Electric Corporation, Research and Development Center (Dr. C. C. Hein, Contract Admin.), Churchill Borough, Pittsburg, Pennsylvania 15235

139 Whittaker Corporation, Power Sources Division (Mr. J. W. Reiter), 3850 Olive Street, Denver, Colorado 80237